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Experimental Study on Structural Damage Detection based on Column like Structure using Natural Frequencies: Review

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***Abstract* - Need for developing efficient non-destructive damage detection procedures for civil engineering structures is growing rapidly. This paper presents a methodology for detection and quantification of structural damage using modal information obtained from transfer matrix technique. Vibration characteristics of beam-like structure have been determined using the computer program developed based on the formulations presented in the paper. It has been noted from reported literature that detection and quantification of damage using mode shape information is difficult and further, extraction of mode shape information has practical difficulties and limitations. Hence, a methodology for detection and quantification of damage in structure using transfer matrix technique based on the changes in the natural frequencies has been developed. With an assumption of damage at a particular segment of the beam-like structure, an iterative procedure has been formulated to converge the calculated and measured frequencies by adjusting flexural rigidity of elements and then, the intersections are used for detection and quantification of damage. Vibrations are characterized by time-varying, more or less periodical processes. The sinusoidal vibration of an electric oscillator, the periodic swinging of a simple pendulum, or the random motion of a building subjected to gusts of wind are typical examples of vibrating systems.**

***Keywords* - Non-destructive, transfer matrix, vibration analysis, crack damage, FFT analyzer, structural systems, non-destructive structural damage, modal properties, frequency domain.**

I. INTRODUCTION

The need for development of an efficient procedure for non-destructive structural damage detection is increasing in order to assess the integrity and serviceability of existing structures. This has led to continued research to develop methods that could identify changes in vibration characteristics of a structure. These methods are based on the fact that modal parameters (notably frequencies and mode shapes, and modal damping) are functions of the physical properties of the structure (mass, damping, and stiffness). Any change in the physical properties, such as reduction in stiffness resulting from cracking or loosening of a connection, will cause detectable change in the modal properties. Various methods have been employed by researchers all over the world for damage detection of structural systems, in frequency domain.
The objective of this study is to analyze the vibration behavior of beams both experimentally subjected to single and multiple cracks under free and forced vibration cases. Besides this, information about the location and depth of cracks in cracked steel beams can be obtained educing this technique. Using vibration analysis for early detection of cracks has gained popularity over the years and in the last decade substantial progress has been made in that direction. Dynamic characteristics of damaged and undamaged materials are very different. For this reason, material faults can be detected, especially in steel beams, which are very important construction elements because of their wide spread usage construction and machinery. Crack formation due to cycling loads leads to fatigue of the structure and to discontinuities in the interior configuration. Cracks in vibrating components can initiate catastrophic failures.
Therefore, there is a need to understand the dynamics of cracked structures. When a structure suffers from damage, its dynamic properties can change. Specifically, crack damage can cause a stiffness reduction, with an inherent reduction in natural frequencies, an increase in modal damping, and a change in the mode shapes. From these changes the crack position and magnitude can be identified. Since the reduction in natural frequencies can be easily observed, most researchers use this feature. Natural frequency of the beam has also been determined and verified experimentally.

II. LITERATURE REVIEW

The analysis of structure vibration is necessary in order to calculate the natural frequency of a structure, and the response of the expected excitation. In this way it can be determined whether a particular structure will fulfill its intended function and, in addition, the result of dynamic loading acting on a structure can be predicted, such as the dynamic stresses, fatigue life and noise levels. There are many sources of vibration in structure to consider and the way of changing the vibration using both active and passive methods require an understanding of their mechanism and controls. As a structure is a combination of parts fastened together to create a supporting frame work, which may be part of building, ship etc system.

The effect of a crack on the deformation of a beam has been considered as an elastic hinge by Chondros and Dimarogonas(1980) .Variations of the natural frequencies were calculated by a Perturbation method. A finite element model has been proposed, in which two different shape Functions were adopted for two segments of the beam, in order to consider the discontinuity of Deformation due to the crack. Cawley and Adams(1979) showed that the stress distribution in avibrating structure was non-uniform and was different for each mode of vibration. Therefore, any local crack would affect each mode differently, depending on the location of the crack.Stubbs(1990) and Chondros and Dimarogonas(1998) used the energy method and the continuous cracked beam theory to analyze transverse vibration of cracked beams. In the analytical study of this problem, two procedures have been used by researchers to quantify local flexibility due to the crack. In the first procedure, a stiffness matrix is constructed for the cracked section, in a similar way as an equivalent spring. In the second procedure which is more practical, a cracked finite element stiffness matrix is constructed and assembled with the non- cracked elements of the structure.

III. DAMAGE DETECTION

Damage detection in a structure is performed in two steps.
First, the finite element model of the cracked cantilever beam is established. The beam is discretized into a number of elements, and the crack position is assumed to be in each of the Elements.
Second, for each position of the crack in each element, depth of the crack is varied. Modal analysis for each position and depth is then performed to find the natural frequencies of the beam. Using these results, a class of three dimensional surfaces is constructed for the first three modes of vibration, which indicate natural frequencies in terms of the dimensionless crack depth and crack position.

IV. DEFLECTION ANALYSIS

To determine the deflection characteristics experimentally for the specimen prepared was developed. A schematic and photograph of experimental setup developed. The experimental setup consists of two L-shaped cast iron end blocks connecting a split type cast iron module at the centre. The three cavities in the central module were used to hold the test rods prepared. The end blocks and the central module were well fastened using screws. The hanger at the end of the rod, used to carry the weights, was made of cast iron. A V-shaped plug in the hanger block match with the V- groove made in the specimen. This helps in exact application of load at the point desired. The weight of the specimen prepared was found out using a common balance.

V. APPARATUS REQUIRED

i. Model hammer.
ii. Accelerometer.
iii. FFT analyzer.
iv. Notebook with PULSE software.
v. Electro dynamic vibration shaker system
vi. Power amplifier cm signal generator
vii. Vibration table
viii. Specimen
ix. Display unit

Experimental set up Scheme

A. Model hammer.

B. Accelerometer.

C. FFT analyzer.

D. Notebook with PULSE software.

E. Electro dynamic vibration shaker system

F. Power amplifier cm signal generator

G. Vibration table

H. Specimen

I. splay units

VI. RESULT AND EXPERIMENTAL SET UP

The connections i.e. accelerometer, modal hammer, laptop and other power connections were made.

- The surface of the beam was cleaned for proper contact with the accelerometer.
- The accelerometer was then attached with the surface of the beam.
- The above connections were made for free vibrations.
- For Forced Vibration, Electrodynamic Vibration Shaker System was used which consist of system.
- Readings were taken for free-free and fixed-free boundary conditions for different steel beams.
- The modal analysis results are compared with FEM package ANSYS and analytical values.

VII. CONCLUSION

- In steel beam free-free condition it was seen that the results were in good co ordinance with theoretical values. The lowest frequency was in lowest mode. The frequency was increasing with each subsequent mode of vibration. The percentage of error was also decreasing as frequency is increasing.
- In first mode the natural frequencies of free – free beam decreases more rapidly for crack close to centre than the ends (i.e. the centre cracks are more affected).
- In second mode the natural frequencies of free – free beam decreases more rapidly for crack close to ends than the centre (i.e. the end cracks are more affected).
- For forced vibration, it was seen that the natural frequencies were nearly similar to that of free vibration.
- It has been found that at various nodes various level of intensities had given the value of cracks.
- The experiment had given the proper analysis of behavior of beam at cracks by using FEM and ANSYS.
- It has provided us the information about the location and depth of cracks in cracked steel beam at various frequencies.
- Development of criteria for depth of a crack especially for steel beams.

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